Detection of Heart Diseases via Telecardiology

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CONTENTS

1. Introduction
    1.1ECG
        1.1.1 Tele-cardiology
        1.1.2 Tele- echocardiograms
        1.1.3 Tele-consultation
        1.1.4 Tele-teaching
    1.2Artifacts/ Noises in ECG Signal
        1.2.1 Power line interference
        1.2.2 Electromyogram (EMG) Noise
        1.2.3 Baseline Wander
    1.3 Cloud Computing
    1.4 Encryption/Decryption in ECG
    1.5 Compression in ECG
    1.6 IOT (Internet of things) in ECG

2. Literature survey

3. Research gaps

4. Problem formulation

5. Objectives

6. Contribution and need of the proposed research

7. Methodology

8. Place of work

9. Resources (Hardware/Software/) required & availability status

10. Extent of external assistance required

11. References

1. Introduction

With the increasing sedentary lifestyle, use of drugs, increasing stress levels, people are becoming prone to cardiovascular diseases (CVDs). CVDs have now become the leading cause of mortality in India; almost covering 34% of all mortality is attributable to CVDs [1]. With a great shortage of doctors and doctor: patient ratio of 1:1700, access to better people looking to enhance the quality of life healthcare seems to be a distant dream [2].Secondly, there is a shortage of adequately trained specialists, technicians, and nurses for cardiology to cater to non-invasive diagnosis, invasive and disease management. India is facing a big challenge of shortage in trained health care personnel at all levels, especially in rural areas. The situation is even worse when it comes to cardiologists. India trains only about 150 new cardiologists every year and the number is not enough given the disease burden. As a result, mortality from CVDs remains high, for instance, the mortality rate due to acute coronary syndrome was 5.5% for the rich, while that for the poor was8.2%. The possible solution for the inequitable distribution of specialists is Tele-Cardiology. Tele-cardiology offers an innovative solution by addressing the severe issue of specialist shortage to provide quality medical service, clinical diagnosis, and disease management in 'Golden hours' for the needy rural population. Cloud/ IoHT based Telecardiology, involving tele-ECG, tele-consultations, tele-echocardiography and e-teaching, offers the best alternative as a cardiologist can give a diagnosis and directing therapy from any major city of India by utilizing his time to diagnose cardiac disorder and review of an ECG of a patient admitted at remote area [3]. As compared with the traditional ECG, this cloud-based pervasive tele-cardiology service can realize interoperability across various mobile and fixed devices by accessing patients' current and past ECG records across hospitals via a centralized cloud database and to provide pre-hospital diagnosis in golden hours. This service advances clinical work and research on 12-lead ECG telemedicine with ECG, as it will inexpensively facilitate the collaborative application of telecardiology across hospitals and expand services from regional to global. The Proposed hybrid mobile-cloud based telecardiology system will be ubiquitous, easy to perform, inexpensive, and beneficial. The system, if established, may be extrapolated to address other healthcare problems by similar methodology. The proposed research will be a reference model for the early and timely detection of cardiac disorders.

1.1ECG

ECG is a tool used for diagnosis and analysis of heart disease at an early stage and used for remotely monitoring of heart disease. It is a graphical representation of an electrical signal produced by the heart in the form of a scanned image. By using ECG data physicians can reduce the diagnose time while checking a patient. ECG signal consists of P wave, QRS wave, T wave and U wave as shown in fig.1. A method used for the detection of heart rate consisting of four steps: preprocessing, feature extraction, heart rate detection, classification. In the first step, the ECG signal is preprocessed means the signal is noise-free. In second step feature extraction is used to indicate/locate the changes in QRS wave, ST-wave and T wave. In the third step heart rate is calculated and in the last step heart rate is classified.

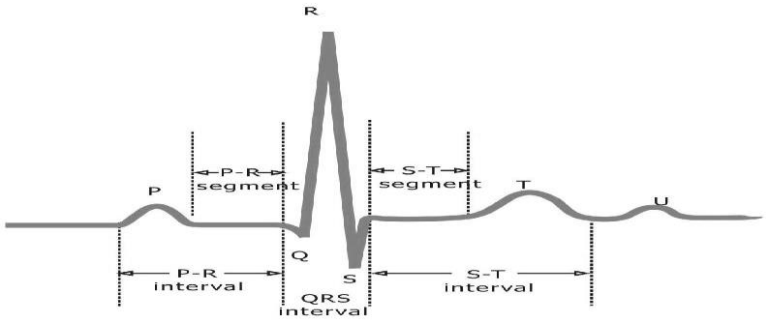

Fig.1 ECG signal

1.1.1 Tele-cardiology

Tele-cardiology offers an innovative solution by addressing the severe issue of specialist shortage to provide quality medical service, clinical diagnosis, and disease management in 'Golden hours' for the needy rural population. This also has applications of pre-Hospital, in-hospital and post-hospital diagnosis. The proposed work may provide support of cardiac experts located at urban areas to rural populations instantly and hence may offer an alternative to existing problem and thus can save human lives living at remote places.

1.1.2Tele- echocardiograms

It is a technique used to treat the individual with diagnosis CVD those who require emergency medical services. Tele-echocardiograms utilize mobile phones for transmission of medical information to provide emergency health care services to remote areas. Tele ECG has a feature of recording the electrical signal of the heart and displays this recording on a mobile phone screen. After completion of recording, information sent to specialists via MMS (multimedia message

services) and doctors give suggestions to the patient. In an emergency case, it also provides service where patient and doctor can communicate with each other that can avoid unnecessary travelling.

1.1.3 Tele-consultation

This technique uses the concept of Telemedicine technology where the people can consult with a highly skilled doctor when needed. Telemedicine utilizes telecommunication technology for medical treatment and patient care. Tele-consultation provides a path to share medical data/ECG signals between online specialists and off-line specialists via mobile phone [3]. In India, Telemedicine technology was very slow due to many reasons but today's scenario has changed its usage is increasing day by day. It will help to remove the shortage of highly skilled doctors in remote areas. Tele-consultation provides clinical treatment and patient can approach highly skilled or experts in remote areas for pre-treatment/advice and reduces the delay in hospital of STEMI of patient [4].

1.1.4 Tele-teaching

In India, there is a shortfall of teachers and pediatric cardiologists in the existing medical colleges. This problem can be solved by adopting a technique known as e-teaching. The advantages of e-teaching are as follow:

(i) By adopting e-teaching only one teacher can teach a large number of students at a time due to this, the problem of shortage of teachers can be reduced.

(ii) The e-classes can be recorded for future purpose and a better learning experience can be achieved by replay it.

Tele-teaching and telecardiology can help to solve the issue of specialist shortfall for teaching, medical diagnosis, and disease management in India [3].

1.2 Artifacts/ Noises in ECG Signal

ECG is a tool used for diagnosis and analysis of heart disease and it records the electrical activity of the heart. During recording the ECG signal gets distorted by noises /artifacts which could change the shape and amplitude of ECG signal or change the characteristics of the ECG waveform that makes detection of ECG signal very difficult [5]. Different types of noises in ECG given below:

- Power line interference

- Electromyogram (EMG) Noise
- Baseline Wander

1.2.1 Power line interference

The power line interference is mainly caused by a stray electromagnetic field or when the ECG machine is not properly connected with the patient. Due to this interference, the ECG signal/ waveform gets contaminated or may obscure completely. This type of noise can be easily detectable because the disturbance voltage in ECG has a frequency range of 50 Hz to 60 Hz. Power Line Interference Waveform as shown in fig.2 [6].

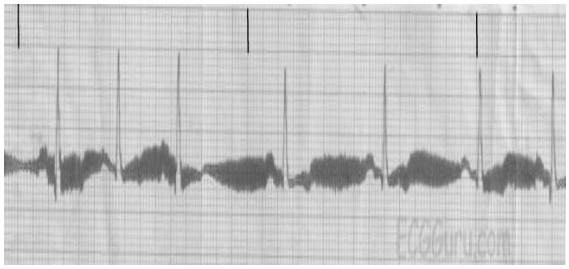

Fig.2 Power Line Interference waveform

1.2.2 Electromyogram (EMG) Noise

The Electromyogram (EMG) noise is generated due to the electrical activity of the muscle contraction or vibration of the human skeleton. EMG consists of a maximum frequency of 10 kHz that creates problem in processing of data and analysis of ECG signal [7]. ECG signal which contains EMG noise as shown in fig.3

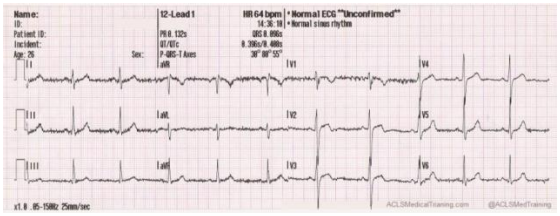

Fig.3Electromyogram (EMG) Noise Waveform

1.2.3 Baseline Wander

Baseline wander is appearing a low-frequency or slow movement artifacts present in the ECG signal. This is mainly due to the vibration of electrode and movement in the human body. Baseline wander has frequency 0.5Hz-1Hz. Due to low frequency, Baseline wander creates problems in recognition and analysis of amplitude of ECG signals [5]. Baseline wanders noises waveform as shown in fig.4

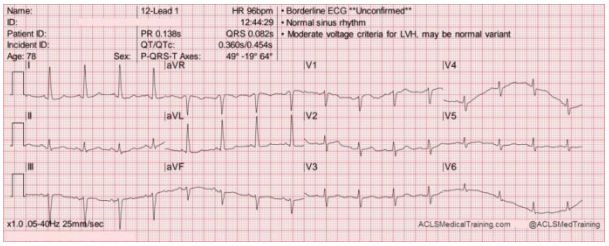

Fig.4 Baseline Wander Noises Waveform

1.3 Cloud Computing

The concept of cloud computing provides the IT resources which contain processing, memory for storage and network when needed. By using the cloud computing technique, the users can access and store all medical information from different locations and effectively utilizing them by collaborating with experts' offers an alternative to being explored for a variety of applications. An interactive portal for hospital, healthcare professionals and medical experts will present effective means for better healthcare services. In the health care system, the cloud is used for continuous monitoring in remote areas and it provides security and privacy to medical information and data can be recovered [8]. Cloud-based approach provides many features: It reduces the cost of usage of computing resources, secondly it can access with web via internet/mobile phone. Following are the key features of cloud computing:

- Resource Pooling and Elasticity
- Self-Service and On-Demand Services
- Pricing
- Quality of Service

1.4 Encryption/Decryption in ECG

ECG is used for the detection or monitoring of the activity of a human heart. ECG data required a large amount of storage, so compressed data is required for transmission. With this compression technique, data must be encrypted [9]. The medical information or health care data is very sensitive strong security should be required to avoid serious problems for analysis. The solution to this problem is done by Encryption/ Decryption. In encryption, data is in encoded format known as cipher text which is not easily understandable by unauthorized users. Encryption allows only authorized persons to access the diagnosis data. It uses a methodology called cryptography which provides security to medical information. After Encryption data is decrypted by humans or machines via a set of keys to the received original signal.

1.5 Compression in ECG

ECG is a tool used for diagnosis and analysis of heart disease at an early stage and used for remotely monitoring of heart disease. It is used for recording of ECG signal. During the recording of the ECG signal, it requires a large amount of space for storage. This is a very big problem in biomedical research. To avoid this problem and for making data more efficient, a technique known as compression can be used [10]. It reduces the amount of data while preserving the signal quality which enhances the transmission speed of the ECG signal and reduces the consumption of energy. It also helps to prevent the loss of important features of the ECG signal. If this happens, it creates a problem for the specialist to evaluate the real-time ECG signal/heart condition. Compression can be classified into two categories lossless and lossy compression. In lossless compression, the reconstructed signal is an exact copy of the original signal with a 0% reconstruction error. The advantage of lossless compression is that it does not reduce the signal quality. Lossy compression presents a reconstructed signal which is close enough to the original signal. It also allows correct analysis of heart condition with a high compression ratio [11].

1.6 IOT (Internet of things) in ECG

It is a technique permits the interconnection between human and things anywhere and at any time. Its functions are not only allowing the connection but also allows the exchange of medical information or data from one place to another for monitoring and provides the better health care services to remote areas/location [12]. The sensors are connected to the internet and users can access this technology known as IOT [13]. It is a network that can be integrated into the global information network. For the diagnosis and treatment of heart disease, a technique known as IoT can be adopted. In the past, doctors had to wait for the patient’s visit but today's scenario has changed no need to wait for patients. By using the concept of IoT, doctors can monitor a patient’s health in real-time. IoT provides a quality of life via continuously monitoring the system. This technique provides health care services at a large distance and also reduces the cost of healthcare by managing the heart disease with no longer stay in hospital and with less traveling time. The advantage of IoT is to continue monitoring the ECG signal of the heart patient and provides an alert message to the patient in an emergency case.

2. Literature Survey

John M. Belmont and Leone F. Mattioli, et.al,(1995) investigated the inter observer reliability and diagnostic validity of an electronic stethoscope for pediatric telecardiology. In this paper, pediatric cardiologists use an electronic (ES) or an acoustic (AS) stethoscope for diagnoses of ECG and the valuation of heart sounds and heart disease. Authors expressed accuracy can be achieved 92%, sensitivity is 88% and specificity is 97% after a combination of hands-on electronic stethoscope (ES) and tele- electronic stethoscope (ES) [14].

John M. Belmont and Leone F. Mattioli (2003) proposed that in pediatric telecardiology reliability and accuracy can be achieved by using wide-bandwidth electronic stethoscope. Same results can also be achieved by narrow-bandwidth telephonic stethoscope (TS) which is cheaper and more convenient than wide-bandwidth electronic stethoscope. Heart disease can be detected by differentiating between functional and organic murmurs by using narrow-band width stethoscope. When a patient with age of atleast 5 years examined by experienced examiner, Maximum accuracy can be achieved. The results like raw agreement 96%, sensitivity 94%, and specificity 100% are achieved, when the older children undergo examination by highly skilled examiner [15].

Fei Hu and De-CunDong(2007)provides a platform based on the wireless interconnection of small ECG sensors called Telecardiology Sensor Networks (TSN). No manpower is required in case of TSN because it's a platform by which low cost automating vital sign monitoring at any time can be done. The updated information for all patients at any time are available in this process. Human processing is time consuming and prone to errors, to avoid such things TSN is much more useful. It also provides security against information stealing and malicious attacks [16].

Chin-Teng Lin and Kuan-Cheng Chang (2010) proposed a newest wireless, ambulatory, real-time intelligent telecardiology system with automatic alarm that integrates all the key elements in one system to improve healthcare for cardiovascular disease. Prevention of disease related to heart is possible by providing information at early stage. It's a power-saving and lightweight device that activates alarm system in case of occurrence of any problems. By this system high sensitivity, specificity and accuracy up to 94% can be achieved [17].

Amit Kumar Manocha, Mandeep Singh (2011) proposed an algorithm for the detection of ischemia in terms of their performance. The performance of any method for ischemia detection can be quantified in terms of its positive predictivity (+P) and sensitivity (Se). Along with positive predictivity and sensitivity, another parameter for the evaluation of algorithms is its speed of

execution. In this paper, the average percentage of sensitivity and positive predictivity of ST-segment in ECG are 87-89 and 90-92 [18].

Sadeer G. Al-Kindi and Reza Tafreshi (2011) introduced a computer algorithm that used a digital scheme for analysis of real-time detection of MI (Myocardial infarction). The proposed algorithm can detect 85% of MI (Myocardial infarction) incidents without any false detection. This algorithm has an upper hand in extracting features of medical data which allows continuous monitoring of the patient activities. The sensitivity and specificity of 85% and 100% can be achieved after usage this algorithm. [19].

Henian Xia and Irfan Asif, et.al, (2013) proposed a cloud-based system for real-time ECG continuously monitoring the heartbeat of the patient. This system aims to use cloud computing techniques for the collection of medical data and transmitted to highly skilled doctors for treatment because shortage of highly skilled doctors in rural areas. In this paper, the authors present an algorithm for the evaluation of medical information [20].

Anpeng Huang, Chao Chen, et.al, (2014) presented an intelligent telecardiology system named as WE-CARE. WE-CARE system uses a tool known as m-Health that is very efficient for the diagnosis of cardiovascular disease. ECG signal consists of QRS and T wave, For the detection of QRS and T wave, this system proposed two algorithms that provide a high detection rate. The rate for the QRS complex detection is 99.3%, and 97.7% rate for T wave detection. The average compression ratio calculated is 5.98 in this paper [21].

DeboleenaSadhukhan, Saurabh Pal, et.al, (2015) introduced an algorithm for the reduction of ECG data using discrete Fourier transforms coefficients. For the selection of these coefficients, the authors proposed two strategies. A fixed strategy depends on the selection of fixed band-limiting frequency and an adaptive strategy that depends on the performance of the signal. By using these techniques, the compression ratio for the fixed strategy is 14.67 and 16.58 for the adaptive strategy can be achieved with better reconstruction quality of signal [22].

Nitha V. Panicker and A. SukeshKumar(2015) developed a tablet PC body sensor system for the diagnosis of heart diseases in remote areas. In case of abnormal conditions, this system provides an alert message to doctors in real-time and doctors provide the medicated advice back to patient. Here the analysis was carried out by taking the example of Wrist sensor and sphygmomanometer for female and male population. The Sensitivity, specificity, and accuracy when comparing the sphygmomanometer and wrist method are shown in the table 1 [23]

Subject	Sensitivity	Specificity	Accuracy

Male (113)	52.63%	94.64%	73.45%
Female(178)	63.49%	95.65%	84.27%
Total (291)	58.33%	95.32%	80.07%

Table 1 shows Sensitivity, specificity, and accuracy of female and male population

Rong Huang and YingchunZhou (2015)presented an efficient and easily interpretable procedure that is used for the detection of cardiac disease by a new feature extraction method and comparison of the classifiers. Here three classifiers are compared 1) Stepwise Discriminant Analysis (SDA) 2) Support Vector Machine (SVM) 3) LASSO logistic regression. For the reduced dimensions, SDA is applied which is the more efficient and more stable procedure. Using this procedure, the value of sensitivity, specificity, and accuracy 89.68%, 84.62%, and 88.52%, respectively can be achieved [24].

Kashfia Sailunaz, Musaed Alhussein, et.al (2016) authors presented a smart and secure cloud-based healthcare monitoring system in the rural areas for the detection of heart diseases. This system evaluates the patients into three different categories—healthy, alarming and emergency. In case of detection of heart problem, it gives a platform for communication between highly skilled doctors and patients for better treatment. The medical information or health care data is very sensitive, Strong security should be required to avoid serious problems for analysis. The solution to this problem is done by Encryption [25].

Amit Kumar and Mandeep Singh (2016) proposed a novel method and window characterization algorithm for the detection of ischaemic episodes. This detection is done by using a coefficient of variation (COV), kurtosis and form factor. The authors presented a bell-shaped normal distribution graph for normal ischaemic ST segments. In this paper, authors achieved an average sensitivity (Se)of 97.71% and positive predictivity (+P) of96.89% [26].

Lucie Marsanoval, Marina Ronzhina, et.al (2017) explained a method for classification of various heartbeats i.e non-ischemic, ischemic. For diagnosis and further treatment of patients its necessary to detect pathological events in ECG. In long term monitoring data required is in bulk and it's a tough job in case of manual evaluation. So, a new method for analysis of ECG records has been developed i.e. cardiac monitoring consisting of automatic analysis of ECG. [27].

Giuseppe Molinari, Martina Molinari, et.al, (2017) discussed the application of telecardiology and its settings in-hospital. It gives a unique feature like tele-consultation, which eliminates unnecessary traveling for both patients and cardiologists. In newborns, heart disease problems can be diagnosed by this technique due to its real-time transmission feature. Telecardiology can also be used in the diagnosis of chest pain with an accuracy of 86.9% and a sensitivity of 97.4% [28].

Isabel de la Torre Dı´ez, Begon˜a Garcia-Zapirain, et.al, (2017) presented a model based on a cloud-based system for a tele-cardiologist. Through this system, a better service can be provided to patients in remote areas. Authors focus on data security and privacy of patient's medical information by using cloud-based computing technology along with smartcard system [29].

Waleed Alsaadi, Ali Serener (2017) examined the performance of ECG signal transmission through a multipath Rayleigh fading channel. Authors used MIMO antenna technology with DVB-T(digital video broadcasting–terrestrial). DVB-T (digital video broadcasting –terrestrial) improves performance by reducing the effect of multipath fading. By using DVB-S2 (digital video broadcasting –satellite version 2) technology performance can be improved of up to 18 dB. For the transmission of ECG signal, DVB-S2 (digital video broadcasting –satellite version 2) technology is preferable because it has more features compare to DVB-T(digital video broadcasting–terrestrial (DVB-T). In this paper bit error rate (BER) of this system is also evaluated [30].

Bollepalli S. Chandraa, Challa S. Sastry, et.al (2017) proposed an ultra-low-cost dictionary-based algorithm for continuously monitoring the heartbeat. Using a dictionary-based algorithm, the authors aim to reduce the cost and detect the heartbeats accurately and transmitted after compression. This compression can be done by using class-specific dictionaries. The advantage of this system is not only the reduction of bandwidth requirement but also reduces the burden of specialists [31].

Mohit Kumar, Ram Bilas Pachori (2017) demonstrates a flexible analytic wavelet transform (FAWT) method for automatic diagnosis of heartbeat. In this method the ECG signal is partitioned into beats then FAWT is applied on each segmented beat which divided into small parts and after division sample entropy (SEnt) is calculated by using random forest (RF), J48 decision tree, back propagation neural network (BPNN), and least-squares support vector machine (LS-SVM) classifiers. After usage of least-squares support vector machine (LS-SVM) highest accuracy can be achieved up to 99.31%. Classification accuracy (%) of LS-SVM (least-squares support vector machine) with different kernel functions for balanced dataset as given in table 2 [32]

Kernal function	Parameter	Sensitivity	Specificity	Accuracy
Linear		84.64	86.83	85.74
Polynomial	x = 2	92.61	95.52	94.06
RBF	*sigma* = 2.2	99.13	97.40	98.27

Table 2 LS-SVM (least-squares support vector machine) with different kernel functions

C. K. Roopa, B. S. Harish (2017) presented different machine learning techniques that are employed for analysis of the ECG signal. These techniques used artificial neural networks, support vector machines, fuzzy logic, decision trees, rough set theory, genetic and hybrid algorithms for accurate detection of the heartbeat of a patient [33].

Fangjian Gao1, Scott Thiebes et.al (2018) presented the concept of cloud computing for the detection of health problems. By using the cloud computing technique, the users can access and store all medical information from different locations. Authors also proposed a taxonomy that provides a scheme which gives information related to cloud computing services to health care patient [34].

Emmanuel Andrès, Samy Talha et.al (2018) investigated new telemedicine projects which used artificial intelligence for the first time to detect heart problems in remote areas. E-care telemedicine projects detected patient's health in worst conditions, with a sensitivity of 100%, specificity of 72%, as well as positive and negative predictive of 90% and 100% [35].

Asiya Sultan, ZIA UR RAHMAN et.al (2018) presented noise cancellers which eliminate the errors in ECG signal based on the Kalman filter. The advantage of the Kalman-based adaptive filter gives noise-free ECG signal. High accuracy can be achieved by using this filter. Authors also express Kalman-based adaptive artifact cancellation structures, which are the combination of various least-mean-square (LMS) algorithms that gives high-quality ECG signal [36].

Tayyaba Tariq, Adil Abbas et.al (2019) presented a sensor bracelet that gives notification to doctors if a patient's heart rate is out of limit and the doctor immediately gives medical advice to patient. This bracelet continuously checks the heartbeat and uploads the data on the website to maintain a patient's history. Authors used a novel technology for patient's easiness that can be used for continuous monitoring of patient's heart rate. In this paper machine learning and circus, tool is used for analysis of data [37].

Azadeh Zamanifar, Eslam Nazemi (2019) introduced a model that requires a large number of sensors for predicting both medical data and the health status of the patient. This model uses a tree-structured network for prediction of health condition with accuracy of 83%. In this paper authors also explain the concept of the internet of things (IoT). This method is very useful for the detection of the current activity of the patient [38].

Marcus A.G. Santos, Roberto Munoz, et.al, (2019) demonstrated about online heart monitoring systems on the internet of health things (IoHT) environments. IoHT is a technique that permits the

interconnection between humans and things at any time at any place. In this paper authors also demonstrate the concept of cloud computing. By using the cloud computing technique, the users can access and store all medical information from different locations and effectively utilizing them. Authors present a reference model for the evaluation of resources, low-cost computing resources for data collection, machine learning algorithms for accurate diagnosis and even prediction of heart diseases [39].

3. Research Gaps

- Cloud/IoHT based Tele-cardiology, involving tele-ECG, tele-consultations, tele-echocardiography and e-teaching, offers the best alternative as a cardiologist can give a diagnosis and directing therapy from any major city of India by utilizing his time to review an ECG of a patient admitted at remote area.
- As compared with the traditional ECG, this cloud-based pervasive tele-cardiology service can realize interoperability across various mobile and fixed devices by accessing patients' current and past ECG records across hospitals via centralized cloud database, and to provide pre-hospital diagnosis in golden hours.
- Apparently, this service advances clinical work and research on 12-lead ECG telemedicine with ECG, as it will inexpensively facilitate the collaborative application of tele-cardiology across hospitals and expand services from regional to global.
- Proposed hybrid mobile-cloud based tele-cardiology system will be ubiquitous, easy to perform, inexpensive, and beneficial. The system, if established, may be extrapolated to address other healthcare problems by similar methodology.

4. Problem formulation

With the increasing sedentary lifestyle, use of tobacco and drugs, increasing stress levels, people are becoming prone to cardiovascular diseases (CVDs). CVDs have now become the leading cause of mortality in India. A quarter of all mortality is attributable to CVD. Unfortunately, India faces a big challenge of shortage in trained health care personnel at all levels, especially in rural areas. With a shortage of 5 Lac doctors and a doctor-patient ratio of 1:1,674, access to better healthcare seems to be a distant dream. The situation is even worse when it comes to cardiologists. India trains only around 150 new cardiologists every year and number is not enough to solve CVDs burden [40, 41]. The one solution for the inequitable distribution of specialists is Tele-Cardiology.

In recent years, revolutionary progress in telecardiology has been made. Essential tools to deliver telecardiology services include wireless communication [42-47], remote wearable ECG monitoring [48-50], cloud computing [51-56] and mobile devices/smartphones [57-59]. Likewise, researchers have evaluated prospects of telemedicine centers in India [60-62], ECG compression techniques [63], body-sensor system for rural telehealth applications [64], establishment of pilot project for cardiac management in Rural Bengal [65] and system for transmission of ECG to sub-center with low bandwidth [66]. Despite the efforts, a mobile telecardiology assistive system for real-time support to cardiac patients has not been developed in India to date. Also, telecardiology has the potential to save time, lives and money.

5. Objectives

1. To identify annotated ECG records from globally available databases and pre-processing of records.
2. To extract features of pre-processed ECG records for classification of cardiovascular disorders.
3. To implement cloud/IoHT web server-based service for seamless and continuous monitoring of cardiac activities and consultations of cardiologists.
4. To enhance the existing performance parameters and validation of results.

6. Contribution and need of the proposed research

- A cloud-based approach to access any data from different locations and effectively utilizing them by collaborating with expert's offers an alternative to be explored for a variety of applications. An interactive portal for hospital, healthcare professionals and medical experts will present effective means for better healthcare services.
- The mobile telecardiology based suggestive solution will provide a cost-effective, efficient and reliable source for providing healthcare assistance with the help of global medical experts. It will also help patients to get proper diagnosis and timely treatment, which may save their lives. The developed technology, if successfully implemented, may open a new panorama in healthcare systems of countries like India by proper utilization of medical facilities by this approach.
- The need for the proposed research is that the population living in rural and distant places is devoid of access to medical experts especially in the field of cardiology. These proposed

technology-based products will help in assessing the advice of doctors from urban places. This will lead to balance at the social level towards assessing of better healthcare services.

- These proposed technologies also lead to the development of a novel diagnostic system for real-time predictive analysis based on ECG data and related health parameters/symptoms. It will also help in getting instant opinions from cardiologists across the globe for better patient management.

7. Methodology

For monitoring of heart disorders annotated ECG records will be identified from available databases worldwide. Then pre-processing of signals will be required to remove the noises, which involves baseline wanders, muscle tremors and sometimes, power line interface. The noises will be handled with advanced algorithms like filters, wavelet transform, principal component analysis, independent component analysis, empirical mode decompositions, etc. The next stage includes the detection of ECG characteristic points of the pre-processed ECG signal. The duration, amplitude and included intervals of P, QRS and T waves will be calculated using dedicated algorithms. This will help to find out various heart disorders or abnormalities, like, ischemia, infarction, arrhythmias, blockage, HRV, PVC, etc. A corresponding data logger of the delineated waves would be generated. This module will be developed in MATLAB. Third stage includes mobile heart monitoring systems which comprises of transmission of analyzed data, for this a dedicated cloud server with internet of health things (IoHT) module will be implemented within primary health care centers/institute by considering the issues of body area network, machine learning/data fusion. A dedicated app will be designed to contact the expert cardiologist through authenticated SMS/email. Data will be shared with an expert cardiologist shall be done as per the given clinical diagnosis and recommendations. In the last stage, mitigating key challenges like Energy of the transmitted signals, security and privacy will be taken care of. The Schematic plan for execution of proposed tele-cardiology-based solution as shown in fig.5 and Methodology involved in Software development and optimization are shown in fig.6

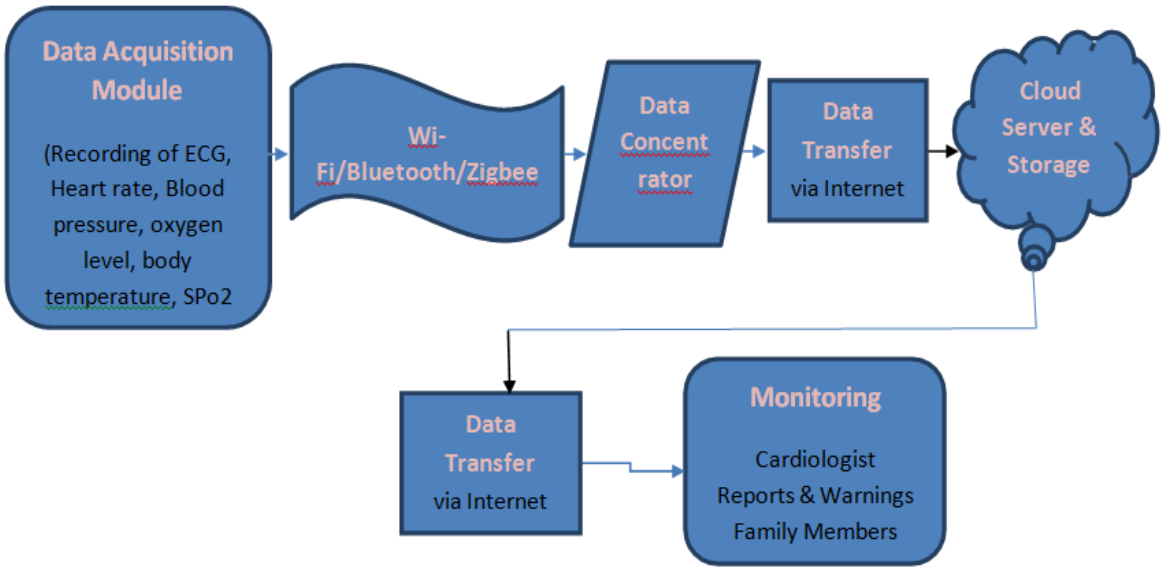

Fig.5 Schematic plan for execution of proposed tele-cardiology-based solution

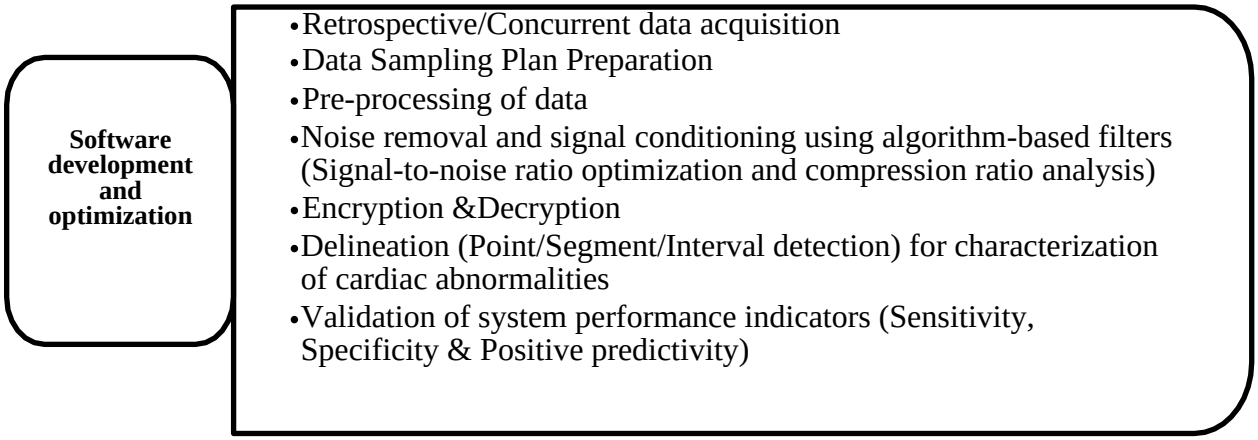
Software development and optimization
•Retrospective/Concurrent data acquisition
•Data Sampling Plan Preparation
•Pre-processing of data
•Noise removal and signal conditioning using algorithm-based filters (Signal-to-noise ratio optimization and compression ratio analysis)
•Encryption &Decryption
•Delineation (Point/Segment/Interval detection) for characterization of cardiac abnormalities
•Validation of system performance indicators (Sensitivity, Specificity & Positive predictivity)

Fig.6 Methodology involved in Software development and optimization

8. Place of Work:

Department of Electronics and Communication Engineering, GZSCCET, Maharaja Ranjit Singh Punjab Technical University, Bathinda and Punjab Institute of Technology, GTB Garh, Moga. Punjab.

9. Resources (Hardware/Software/) required & availability status:

MATLAB, analysis software is available in above mentioned Institutes and Data will be collected through Annotated ECG freely available databases like in www.physionet.org

10. Extent of External Assistance Required (if any): NO

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